NPL REPORT CMAM 25

REPORT

Trials of New Sound Level Meter Verification Tests Euromet Project no. 394

Susan P Dowson

September 1998

NPL
National Physical Laboratory

The National Physical Laboratory is operated on behalf of the DTI by NPL Management Limited, a wholly owned subsidiary of Serco Group plc

TRIALS OF NEW SOUND LEVEL METER VERIFICATION TESTS
EUROMET PROJECT No. 394

Susan P Dowson
Centre for Mechanical and Acoustical Metrology
National Physical Laboratory
Teddington
Middlesex TW11 0LW
United Kingdom

ABSTRACT

The current Standards for sound level meters are at present being revised into a new single document, IEC 61672, which will contain specifications, tests and test methods. These test methods will cover both pattern evaluation of new models of sound level meters and periodic verification of individual specimens. The aim of this project was to perform trial sound level meter verifications using the draft of IEC 61672 current at the start of the project, and to report any problems encountered in interpreting the text or applying the tests to the IEC Working Group responsible for the new standard. In addition valuable data on uncertainties of measurement was sought. The project was organised through Euromet which is a forum for collaboration and research between national metrology institutes from countries within Europe. Twelve European institutes participated and this report gives details of the project and of the conclusions reported to the IEC Working Group.

© Crown Copyright 1998
Reproduced by permission of the Controller of HMSO

ISSN 1369-6785

National Physical Laboratory
Queens Road, Teddington, Middlesex, TW11 0LW

Extracts from this report may be reproduced providing the source is acknowledged and the extract is not taken out of context.

Approved on behalf of the Managing Director, NPL,
by Dr G R Torr, Director, Centre for Mechanical and Acoustical Metrology

CONTENTS

PAGE

1 INTRODUCTION

The current international specification standards for sound level meters, IEC 60651 'Sound level meters'[1] published in 1979, and IEC 60804 'Integrating-averaging sound level meters'[2] published in 1985 have long been considered in need of revision. The international committee responsible for specification standards for acoustical instruments, IEC/TC29, therefore set up a Working Group (WG4) to write a replacement for these two standards. The WG has been working for several years on this difficult task, and is producing a single document to cover all sound level meters. The extent of the testing necessary to demonstrate that a new model of instrument conforms to the Class claimed by the manufacturer and the extent necessary for regular verification of individual specimens of instrument has always caused considerable discussion. The new standard, IEC 61672:199X (still at the draft stage) therefore includes two annexes giving tests and test methods for both the full pattern evaluation of new models of instrument (annex A) and for the limited periodic testing of individual specimens (annex B).

This Euromet project used the draft version of the new standard current at the time the project began (1CDV - April 1997[3]) and evaluated the application of the tests described in annex B, by performing trial sound level meter verifications. IEC/TC29 has recently decided that all specification standards it publishes must now include a contribution for uncertainties of measurement of the testing laboratory within its specification tolerances, and the lack of uncertainty data from national laboratories was a major cause for concern, a point which this project also addressed.

1.1 Aims of the project

The project was considered mainly as a co-operation in research, rather than an intercomparison, although considerable comparison of data has been possible.

The project had six main aims:

- to make measurements according to annex B of 1CDV and ensure the tests could be performed and that the text was unambiguous
- to obtain test results and gain important data on measurement uncertainties from different laboratories
- to compare test methods
- to consider whether any improvements were necessary to the wording of annex B for clarification or to avoid misinterpretation
- to report any changes required to IEC/TC29 WG4 'Sound level meters'
- to compare results where appropriate.

This project was <u>not</u> intended as a test to determine whether a particular meter conformed to the new standard.

1.2 Participating laboratories

A total of 12 laboratories participated in the project. They were:

National Physical Laboratory (NPL)	United Kingdom
Bundesamt für Eich-und Vermessungswesen (BEV)	Austria
Danish Primary Laboratory for Acoustics (DPLA)	Denmark
Laboratorie National d'Essais (LNE)	France
Physikalisch Technische Bundesanstalt (PTB)	Germany
National Office of Measures (OMH)	Hungary
Istituto Elettrotecnico Nazionale (IEN)	Italy
Laboratório Nacional de Engenharia Civil	Portugal
Slovak Institute of Metrology (SMU)	Slovak Republic
Instituto de Acústica del Consejo Superior de Investigaciones Cientificas (IA-CSIC)	Spain
Swedish National Testing and Research Institute (SP)	Sweden
Swiss Federal Office of Metrology (OFMET)	Switzerland

NPL acted as the co-ordinating laboratory for the project. Each participant measured one sound level meter, and each meter was also tested by NPL.

Full details of all the participants are listed in Appendix 1.

1.3 Sound level meters under test

Sound level meters from six different manufacturers comprising ten different models were used for the testing. In many cases this was due to the generosity of the manufacturer in supplying a free loan instrument for the project. Other instruments were kindly lent by the participants. The six manufacturers were Brüel & Kjær, CEL Instruments Ltd, Dicesva, 01 dB, Norsonic and Rion. Full details of manufacturers and suppliers are given in Appendix 2.

2 BASIS OF TESTING

The test protocol was based on annex B of IEC 61672 - 1CDV, and was agreed by the participants at the start of the project. Some of the tests in annex B were slightly modified to reduce testing time and hence costs, but both acoustical and electrical testing were included.

With one exception each sound level meter tested had a sound calibrator associated with it. A single output level was used for each sound calibrator both by the co-ordinating and testing laboratory. This was to avoid the situation of both the co-ordinating and testing laboratory calibrating the sound calibrator and then using their own result. Such a procedure would introduce a further variable to the project, which could detract from the comparison of results of the sound level meter tests.

For some of the meters it was necessary initially to define limits for ranges etc. where suitable information was not available in the current instruction manual. In most cases these were defined by the manufacturers who loaned instruments for the project, or by the participants who supplied their own meters. A specification sheet which requested the necessary information was used to provide the basic data on each sound level meter. In general, the meters used had not been manufactured to meet the requirements of the new draft standard, hence the need for some additional information to be supplied/agreed, to ensure both the co-ordinating laboratory and the testing laboratory worked within the same defined limits. All the meters tested were capable of measuring SPL and L_{eq} and had at least 2 frequency weightings.

The general requirements for testing eg. traceability of relevant equipment, and the methods given in annex B of IEC 61672 - 1CDV were to be followed by all participants.

2.1 Test protocol

The test protocol refers directly to annex B of IEC 61672 - 1CDV. It is not possible to include all the text of annex B in this report, but it should be possible to obtain copies of the complete 1CDV document from the national committee of any participating country which is a member of IEC, or from IEC Central Office. The reference for the document is 29/362/CDV.

However to give some information on the extent of the testing performed, the agreed test protocol is reproduced below, followed by table 1 which gives a summary of the details of the tests.

<u>Agreed test protocol:</u>

‘a) *Preliminary inspection* - as B.3 of IEC 61672 - 1CDV.

b) *Acoustical sensitivity* - prior to performing any tests, the associated sound calibrator shall be applied to the instrument, whose sensitivity level shall then be adjusted to indicate the equivalent free-field level supplied according to B.4.1 of IEC 61672 - 1CDV. This free-field level will either be supplied by the co-ordinating laboratory if it has already made measurements on the test meter, or by the participating laboratory if it is testing the meter before the co-ordinating laboratory.

c) *Environmental conditions* - wherever possible measurements shall be made at conditions within the following limits (B.4.2 of IEC 61672 - 1CDV):

Static pressure : 973 mbar - 1033 mbar
Air temperature : 18 °C - 25 °C
Relative humidity : 40% - 70%

Within these limits no adjustments to reference environmental conditions are required.

Where the environmental conditions are outside these limits, the adjustments specified in the instruction manual for the sound level meter shall be applied to the indicated levels, to refer them to reference environmental conditions.

The environmental conditions for each test shall be stated.

d) *Accuracy of indication at 1 kHz under reference conditions* - using the method in B.5.2.1 and B.5.2.6 of IEC 61672 - 1CDV, unless the laboratory does not have a free-field facility. In this case, and only if measured data are available for the difference at 1 kHz between the free-field response in the reference direction and the pressure response of the sound level meter, the method described in B.5.2.2 - B.5.2.5 may be used. Otherwise the laboratory cannot perform a verification of the model of sound level meter under test.

e) *Frequency weightings; frequency response* - all frequency weightings and responses shall be measured with electrical signals **only**, using the method given in B.5.3.1, B.5.3.4 and B.5.3.5 of IEC 61672 - 1CDV. The *electrical response* relative to 1 kHz shall be calculated. No adjustments for the frequency response of the microphone or for reflections or diffraction shall be made for the purposes of this project.

f) *Steady level linearity and under-range indication* - as B.5.4 of IEC 61672 - 1CDV.

g) *Toneburst response for conventional sound level meters* - as B.5.5 of IEC 61672 - 1CDV.

h) *Toneburst response for integrating-averaging and integrating sound level meters* - as B.5.6 of IEC 61672 - 1CDV.

i) *Overload indication* - as B.5.7 of IEC 61672 - 1CDV.

j) *Peak C-weighted sound pressure level* - as B.5.8 of IEC 61672 - 1CDV.

k) *Reset* - as B.5.9 of IEC 61672 - 1CDV.

l) *Power supply* - as B.5.10 of IEC 61672 - 1CDV.

m) *Acoustical tests* - as B.5.11 of IEC 61672 - 1CDV, using the method from B.5.11.4 a). If a free-field facility is not available, methods B.5.11.4 b) or B.5.11.4 c) may be used assuming measured data are available either for the difference between the free-field response in the reference direction and the pressure response of the complete instrument or for the difference between the free-field response in the reference direction and the response of the complete instrument to the electrostatic actuator, as appropriate. Otherwise the laboratory cannot perform a verification of the model of sound level meter under test.'

Table 1 Summary of details of tests performed

Test	Method	Summary
a	Visual/ mechanical	Visual inspection of components; check of operation of switches; ensuring power supply within operating limits specified
b	Acoustical	Adjustment of meter sensitivity using supplied sound calibrator and adjustments required for display of equivalent free-field sound pressure level
c	Environmental	Noting environmental conditions for each test (p, t and RH). If not within specified limits, application of corrections given in instruction manual to relevant data
d	Acoustical free-field or use of calibrated sound calibrator if appropriate corrections available	Determination of accuracy of indication of the sound level meter at 1 kHz
e	Electrical	Measurement of all frequency weightings and responses supplied, *but only electrically,* from 63 Hz to 16 kHz. All results referenced to indication at 1 kHz. No corrections applied for reflection, diffraction or microphone response
f	Electrical	Measurement of linearity, under-range and overload on all ranges at 31.5 Hz, 1 kHz and 12.5 kHz for both SPL and L_{eq} using continuous signals
g	Electrical	Applies single tonebursts of specified durations
h	Electrical	Applies single tonebursts of specified durations and sequences of tonebursts
i	Electrical	Measures point of overload indication with a positive and negative half-cycle signal
j	Electrical	Ability to measure peak C-weighted sound pressure levels measured by application of single and half-cycle signals
k	Mechanical	Checks ability of reset facility to cancel previous display and indication and ensures no spurious indications produced
l	Acoustical	Verifies indication when power supply reaches minimum specified limit, by monitoring change in response to applied sound calibrator
m	Acoustical	Free-field or by use of sound calibrator or electrostatic actuator (assuming required corrections are known) - only performed where frequency weighting has been measured electrically. Checks performance of complete meter with acoustical signal at 125 Hz and either 4 kHz or 8 kHz

2.2 Distribution of equipment

Table 2 shows the equipment used for the project, and the country it was distributed to/supplied from.

Table 2 Sound level meters and sound calibrators used for the project

Manufacture and model of sound level meter; serial no.	Manufacture and model of sound calibrator; serial no.	Supplier SLM / Sound calibrator	Organisation/ Country testing	Order of testing
Rion NL15; 00670515	Brüel & Kjær 4230; 960835	Meyvis/ NPL	OFMET/Switzerland	NPL/OFMET
Rion NL18; 01260348	Brüel & Kjær 4231; 1883425	Meyvis/NPL	SMU/Slovakia	NPL/SMU
Norsonic 110; 12345	Norsonic 1443; 21384	Norsonic	OMH/Hungary	NPL/OMH
CEL 593; 094275	CEL 284/2; 0816160	CEL Instruments Ltd	IEN/ Italy LNEC/Portugal	NPL/IEN/LNEC
Brüel & Kjær 2236A; 2030553	Brüel & Kjær 4231; 1897687	Brüel & Kjær	PTB / Germany	PTB/NPL
Brüel & Kjær 2260; 2076300	Brüel & Kjær 4231; 2061725	Brüel & Kjær	DPLA / Denmark	DPLA/ NPL
Brüel & Kjær 2230; 1385729	Brüel & Kjær 4231; 1730793	SP	SP / Sweden	SP/NPL
01 dB SIP95; 971056	LNE own	01 dB/ LNE	LNE/ France	LNE/NPL
Cesva SC-20c; T 207155	Cesva CB-5; 025844	Dicesva	IA-CSIC / Spain	IA-CSIC/NPL
Norsonic 110; 19611	Brüel & Kjær 4231; 1770769	Norsonic/ BEV	BEV / Austria	BEV/ NPL

The logistics of the project meant that the co-ordinating laboratory did not always perform the measurements first. In some cases the participant completed their tests and then supplied the instrument for testing to NPL. The order of testing is shown in the last column of table 2. The first laboratory to perform the tests calibrated the sound calibrator and supplied the calibration figure to the other laboratory.

2.3 Information to be supplied by participants

Following their measurements each participant agreed to supply the following information:

- a brief description of the method used for all the tests
- full test results
- calculations of the expanded uncertainty of measurement, for a coverage factor k = 2 using the method given in the ISO Publication 'Guide to the expression of uncertainty in measurement', 1995[4]
- details of any problems encountered in applying annex B

- suggestions for improving the clarity of the text in annex B
- an estimate of the time taken to perform the tests.

3 EQUIPMENT, METHODS AND INITIAL FINDINGS

All participants separately interpreted the methods given in annex B of 1CDV. Particular points to note including, where supplied, a list of the equipment used by the participants are detailed in this section.

3.1 NPL (UK)

As the co-ordinating laboratory, NPL performed measurements according to annex B of 1CDV on all 10 meters supplied. Some participants were also able to make free-field measurements of one frequency-weighting, and for these meters NPL also made measurements in the free-field. As stated earlier, where NPL measured the sound level meter before the testing laboratory, the sound calibrator was also calibrated.

3.1.1 **Calibration of sound calibrators and initial adjustment of sound level meters**

Sound calibrators were calibrated using the insert voltage method, with an appropriate calibrated microphone as the reference. Five determinations of the sound pressure level, frequency and total harmonic distortion were made for each device. When necessary, the sound pressure level measured was corrected by use of manufacturer's data to the standard atmospheric pressure of 101.3 kPa.

All sound level meters which NPL measured first were adjusted to read correctly using the associated sound calibrator, following the relevant manufacturer's instructions. For sound level meters that NPL received following measurement by another participant, the associated sound calibrator, when supplied, was applied to the sound level meter and the indication noted. The meter was then tested as received.

3.1.2 **Equipment**

<u>Electrical tests</u>
Philips Function Generator type PM5138A
GDS Attenuator type EL-100
Keithley Multimeter type 2001
HP Vectra PC type QS/20

<u>Acoustical tests</u>
EG & G Lock-in amplifier type 5209
GDS Attenuator type EL-100
Thurlby-Thandar Frequency counter type TF 830
Datron DVM type 1061
Keithley DVM type 197A
Wavetek Signal Generator type 23
Brüel & Kjær type 4180
Rolec Power Amplifier Minbloc 2
HP Vectra PC type QS/20
Loudspeaker
Oscilloscope

3.1.3 **Methods**

For both the electrical and free-field measurements the instruments were under computer control via a GPIB interface. Annex B of IEC 61672 1CDV was followed for developing the software for the electrical tests, and annex A for the acoustical tests, with both programs written under the National Instruments Labwindows environment.

Frequency weightings: Electrical measurements performed through the appropriate capacitance / adaptor, over the frequency range 31.5 Hz to 16 kHz, and results normalised to 1 kHz.

Steady level linearity and under-range indication: Measurements performed for both sound pressure level with time weighting F and L_{eq} at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges. Starting points were derived as described in annex B and the level linearity error was derived by calculating the steady level difference at the point minus the steady level difference at the reference sound pressure level at 1 kHz minus the corresponding measured electrical frequency weighting. In fact a calibrated attenuator was used, and as the input voltage was kept constant to the attenuator, at each point it was only necessary to calculate the difference in attenuator setting at the point and the setting used at the reference sound pressure level.

Toneburst response for conventional sound level meters: The max. hold facility was used to measure the response to the bursts for both A-weighting and C-weighting.

Toneburst response for integrating-averaging sound level meters: For L_{eq} 4 kHz tonebursts of durations 0.25 ms, 5 ms and 100 ms with repetition periods of 200 ms, 500 ms and 5s were used to check the response.

Overload indication: Initially measured in terms of the indication displayed at overload by the sound level meter, but some additional tests performed in terms of the generator voltage necessary to produce overload indication.

Peak C-weighted sound pressure level: Measurement according to 1CDV showed problems due to the noise floor of the instrument on the most sensitive range and at the lowest measurement point on the reference range.

Power supply: The instruments were tested using an external power supply.

Acoustical tests: These were performed in a free-field room using a half-inch laboratory standard microphone as reference. At least the accuracy of indication measurement at 1 kHz was performed acoustically, and where other participants had made a complete measurement of a frequency weighting or response, the same weighting/response was used by NPL where possible. The frequency range used varied from test to test, depending on the requirements, but the range limits were 125 Hz to 20 kHz.

3.2 BEV (Austria)

Sound level meter: Norsonic Analyser type 110
Sound calibrator: Brüel & Kjær type 4231

3.2.1 Initial adjustment

The sensitivity of the analyser was set to -26.7 dB re 1V/Pa.

3.2.2 Equipment

Brüel & Kjær Sine Generator type 1051

Brüel & Kjær Test Waveform Generator type 5918
Frequency Counter type HP 53131A
Datron DVM type 1281

3.2.3 **Methods**

Frequency weightings: The level of the input signal was modified in accordance with the nominal design goal as the frequency was varied. A reference level of 94 dB (not 114 dB as expected) was assumed and the results were normalised to 1 kHz. Conformance was checked against one-half of the tolerances, as only an electrical test was being performed.

Steady level linearity and under-range indication: Measurements performed for both time weighting F and L_{eq} at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz, using 10 dB steps on all ranges. However it appears that the definition of level linearity error was misunderstood and results were referred to the starting point on the range rather than calculating the error according to the definition given in 1CDV.

Toneburst response for integrating-averaging sound level meters: For L_{eq} the number of tonebursts in each sequence was ten.

Overload indication: Measured in terms of the indication in dB produced at overload.

Peak C-weighted sound pressure level: Measurement according to 1CDV showed problems due to the noise floor of the instrument at the lowest measurement point on the reference range. No measurements performed on the most sensitive range.

Accuracy of indication at 1 kHz and other acoustical tests: These were performed in a free-field room using a half-inch laboratory standard microphone as reference. Measurements were made in one-third octaves over the frequency range 125 Hz to 12.5 kHz. At 1 kHz the insert voltage method was used to determine the accuracy of indication, but at other frequencies a relative measurement was performed.

3.3 DPLA (Denmark)

Sound level meter: Brüel & Kjær type 2260
Sound calibrator: Brüel & Kjær type 4231

3.3.1 **Initial adjustment**

The acoustical sensitivity was checked by use of the sound calibrator, using the built-in calibration procedure of the sound level meter, which automatically calculates and displays the corresponding microphone sensitivity. The sensitivity displayed was -27.5 dB re 1V/Pa.

3.3.2 **Equipment**

Brüel & Kjær Sine Noise Generator type 1049
Brüel & Kjær Frequency Analyser type 2120
Brüel & Kjær 10 dB step attenuator type 115022
Brüel & Kjær 1 dB step attenuator type 115021
Toneburst Generator GR type 1396-B
Wavetek Generator type 275
Multi-function acoustic calibrator Brüel & Kjær type 4226
Oscilloscope

3.3.3 **Methods**

Frequency weightings: Electrical measurements were performed over the frequency range 31.5 Hz to 16 kHz. Although not required by this project, correction figures for the microphone response and the effect of the case were then applied to convert these measurements to give the free-field response of the instrument, relative to 1 kHz.

Steady level linearity and under-range indication: Measurements performed for both time weighting F and L_{eq} at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges, using an amplifier for the highest range. However it appears that the definition of level linearity error was misunderstood and the level linearity error was not calculated according to the definition given in 1CDV. Two attenuators were used to enable the total range of the type 2260 to be tested.

Toneburst response for conventional sound level meters: The max. hold facility was used to measure the response to the bursts.

Toneburst response for integrating-averaging sound level meters: For L_{eq} 4 kHz tonebursts of durations 0.25 ms, 5 ms and 100 ms with repetition periods of 200 ms, 500 ms and 5s were used.

Overload indication: Measured in terms of the generator voltage necessary to produce the first indication of overload.

Peak C-weighted sound pressure level: Measurement according to 1CDV showed problems due to the noise floor of the instrument on the most sensitive range and at the lowest measurement point on the reference range. Hence measurements were performed at a level of 3 dB below the upper boundary of the range, 20 dB above the lower boundary and mid-way between the upper boundary and the lower measurement level on the reference range only.

Power supply: The instrument was tested using an external power supply.

Accuracy of indication at 1 kHz and other acoustical tests: These were performed initially by correcting the electrical response for the effect of the microphone and case of the sound level meter (method a), and then by using the type 4226 sound calibrator (method b). As the microphone type used on the sound level meter (a type 4189) is not on the specification list for the type 4226 free-field levels, the pressure to free-field corrections from the microphone calibration chart were applied. Method (a) was thought likely to be the most correct.

3.4 LNE (France)

Sound level meter: 01 dB type SIP95
Sound calibrator: LNE calibrator

3.4.1 **Initial adjustment**

The acoustical sensitivity was checked by use of the sound calibrator, and using the manufacturer's instructions on the free-field correction factor.

3.4.2 **Equipment**

Tektronix Generator type SG 5010, modified by LNE for pulse range capability

External 600 ohms attenuator, made by LNE, 2 times 40 dB, 20 dB and 10 dB
Hewlett Packard Multimeter type 34401A
Rohde & Schwartz Audio Analyser type UPD (for positive and negative half-cycle signal)
Hewlett Packard Waveform Generator type 33120A
Hewlett Packard Digital Frequency Analyser type 3565

3.4.3 **Methods**

For the electrical tests except those requiring half-cycle signals, the equipment was driven by a computer though the IEEE 488 bus. Specific LNE software allowed the generation of the specified electrical signals. Equivalent electrical levels were calculated from the reference voltage noted when the preliminary calibration was performed.

Frequency weightings / responses: Electrical measurements were only performed at 63 Hz. Other weightings were measured acoustically using the a. c. output, which is not a standard test according to IEC 61672 1CDV.

Steady level linearity and under-range indication: Measurements performed for both time weighting F and L_{eq} at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges. However it appears that the definition of level linearity error was misunderstood and results were referred to the starting point at the frequency rather than calculating the error according to the definition given in 1CDV. On the 40 - 140 dB range the reference level was deduced from the a.c. output voltage drop when switching from the reference level range and using a sound calibrator.

Overload indication: Measured in terms of the indication in dB produced at overload.

Power supply: The instrument was tested using an external power supply.

Accuracy of indication at 1 kHz and other acoustical tests: These measurements were performed in a free-field environment using two techniques. The first was the classical method using a sine wave generator driven by a computer. The reference microphone was located at a reference point in front of a loudspeaker. At a given frequency, the level at the reference microphone was adjusted by computer to be 84 dB, and the generator output recorded. The reference microphone was then replaced by the sound level meter and the sound level meter a.c. output was recorded for the same generator outputs. The frequency steps corresponded to 200 points per decade and the frequency range was 80 Hz to 20 kHz. In order to reduce the spurious frequency response variations produced by a small change in the sound level meter location or atmospheric conditions between the two measurements, the recorded curve was smoothed. The second method used a pseudo-random wave generator and an FFT analyser. The analyser frequency steps were 8 Hz and the upper limit of the frequency range was 25 kHz. Two transfer functions were recorded between an arbitrary microphone located at 25 cm from the loudspeaker, and alternatively, the reference microphone and the sound level meter. The inverse Fourier transform of the ratio of the two recorded transfer functions was computed, and the resulting time response windowed in order to discard long distance echoes (the cutting distance was about 1.5 m). The residual long distance echoes of this function showed that the acoustical disturbances were not exactly the same in the two configurations. The goal was then to treat the sound level meter response in order to have the same echo pattern as for the reference microphone. An electrical signal was then applied to the sound level meter in order to produce the same a.c. output level as was recorded at each of the nominal one-third octave frequencies. The values displayed for the appropriate weightings were noted. The results reported by LNE are those measured using the second technique, and they also reported that there were no significant differences between the results obtained using the two techniques. Measurements were quoted at one-octave intervals between 125 Hz and 16 kHz for frequency weightings A and C, and for frequency response Lin. It should be noted that using the a.c. output from the meter is not the method specified in IEC 61672.

Other points: The sound level meter was found to have an unexpectedly long stabilization time following switch-on. All the tests were therefore performed after a warm-up period of 15 minutes, otherwise differences of 0.2 dB or greater could occur.

3.5 PTB (Germany)

Sound level meter: Brüel & Kjær type 2236
Sound calibrator: Brüel & Kjær type 4231

3.5.1 **Initial adjustment**

The acoustical sensitivity was checked by use of the calibrated sound calibrator.

3.5.2 **Equipment**

Hentschel SK-148 Electrical Control Unit

3.5.3 **Methods**

Steady level linearity and under-range indication: Measurements performed for both time weighting F and L_{eq} at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges. On ranges other than the reference range more points were measured than required by annex B. However it appears that the definition of level linearity error was misunderstood and results were referred to the starting point on the range rather than calculating the error according to the definition given in 1CDV.

Toneburst response for integrating-averaging sound level meters: For L_{eq} the number of tonebursts in each sequence was ten.

Overload indication: Measured in terms of the indication in dB produced just before overload indication.

Peak C-weighted sound pressure level: Measurement according to 1CDV showed problems due to the noise floor of the instrument on the most sensitive range.

Accuracy of indication at 1 kHz and other acoustical tests: These were performed in a free-field environment for frequency-weighting A and frequency response LIN over the frequency range 25 Hz to 20 kHz in one-third octaves.

3.6 OMH (Hungary)

Sound level meter: Norsonic type SA 110 analyser
Sound calibrator: Norsonic type 1443

3.6.1 **Initial adjustment**

The sensitivity of the sound level meter was checked with the sound calibrator supplied. The meter had already been measured at NPL, and no adjustment was required showing that the instrument had not changed in sensitivity.

3.6.2 **Equipment**

Attenuator type R-S 334.6010.02
Programmable Oscillator type K-H 4180-1
Programmable crystal controlled Function Generator type TR-0467
Brüel & Kjær multi-function sound calibrator type 4226.

3.6.3 **Methods**

Frequency weightings / responses: Electrical measurements performed through the type 1447 adaptor supplied, over the frequency range 10 Hz to 20 kHz, at one-third octave intervals although this detailed testing was not required by the project. The generator level was kept constant at all frequencies.

Steady level linearity and under-range indication: Measurements performed for time weighting F at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges. Measurements of L_{eq} were made only on the reference range to save time. The actual level linearity errors were not calculated. The meter appeared to have no under-range indication.

Toneburst response for integrating-averaging sound level meters: No tests were performed for L_{eq}.

Overload indication: Measured in terms of the indication in dB produced at overload for one-half cycle signals.

Peak C-weighted sound pressure level: This is only available for half-cycle signals on this meter. Measurement according to 1CDV showed problems due to the low level of signal at the mid-way point and 3 dB above the lower boundary on the most sensitive range.

Power supply: The instrument was tested using an external power supply.

Accuracy of indication at 1 kHz and other acoustical tests: Accuracy of indication at 1 kHz was performed simply by applying the Norsonic calibrator supplied. Other acoustical tests were performed on frequency-weighting C, measuring the meter pressure response with a Brüel & Kjær type 4226 multi-function sound calibrator. For simple verifications OMH normally measure acoustically with the sound calibrator set to pressure, as they do not have free-field facilities. Where free-field measurements are required another laboratory performs the tests.

3.7 IEN (Italy)

Sound level meter: CEL type 593
Sound calibrator: CEL type 284/2

3.7.1 **Initial adjustment**

The sound level meter was calibrated using the sound calibrator, setting-up to a value of 114.0 dB. No adjustment was necessary showing that the instrument had not changed in sensitivity.

3.7.2 **Equipment**

For the electrical tests:
Multimeter type HP 3458A
Brüel & Kjær Signal Generator type 1049
Keithley Function Generator type 4930A

For the acoustical free-field tests:
Generator type HP 33120A
Brüel & Kjær Microphone type 4190 with Preamplifier type 2639
Brüel & Kjær Audio Power Amplifier type 2706
Brüel & Kjær Microphone type 4180 with Preamplifier type 2669B
Brüel & Kjær Analyser type 2133
Loudspeaker

3.7.3 **Methods**

Frequency weightings / responses: The electrical input signal was modified according to the inverse of the nominal weighting under test, in order to maintain a constant theoretical indication. Reference level used was 90 dB, not the expected 114 dB.

Steady level linearity and under-range indication: Measurements performed for time weighting F only at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges. On the reference range 1 dB steps were used to determine the upper and lower boundaries, overload and under-range. On other ranges at least three points were measured: the reference level plus the nominal attenuation of the range, at the lower boundary, at the upper boundary and in 1 dB steps from the upper boundary to overload. However it appears that the definition of level linearity error was misunderstood as it was not calculated according to the definition given in 1CDV. The starting points used, which were used as the reference points for level linearity error, appeared to be the same at all frequencies.

Overload indication: Measured in terms of the indication in dB produced at overload for a one-half cycle signal.

Peak C-weighted sound pressure level: Measurement according to 1CDV showed problems due to the noise floor of the instrument at the lowest measurement point on the reference range, and at the midway point and lowest point on the most sensitive range.

Accuracy of indication at 1 kHz and other acoustical tests: These were performed in a free-field room, using a half-inch laboratory standard microphone as reference. Measurements were performed three times at frequencies of 125 Hz, 1 kHz, 4 kHz and 8 kHz, using a nominal level of 70 dB except at 125 Hz where the level was slightly lower due to the loudspeaker used.

3.8 LNEC (Portugal)

Sound level meter: CEL type 593
Sound calibrator: CEL type 284/2

LNEC joined the project late, but managed to perform most of the tests.

3.8.1 **Initial adjustment**

The sensitivity of the sound level meter was checked with the sound calibrator supplied. The meter had already been measured at NPL. The value indicated was 0.4 dB higher than at NPL - the meter was then adjusted under 3.8.3.

3.8.2 **Equipment**

Brüel & Kjær Sine Noise Generator type 1049
Attenuator type WB 1099
Brüel & Kjær Test Waveform Generator type 5918

3.8.3 **Methods**

Frequency weightings: The input level was maintained constant at all frequencies, to give an indication of 80 dB for frequencies other than 1 kHz.

Steady level linearity and under-range indication: Measurements performed for time weighting F only at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges, using the high output of the waveform generator for levels greater than 134 dB. The level linearity error was calculated according to the definition given in 1CDV, and the starting points were used, but the nominal electrical frequency weighting was applied before calculation of the level linearity error.

Toneburst response for conventional sound level meters: The generator was triggered manually.

Toneburst response for integrating-averaging sound level meters: The generator was triggered manually.

Accuracy of indication at 1 kHz and other acoustical tests: Accuracy of indication was performed only in terms of adjusting the meter to read correctly in response to the associated sound calibrator. No other acoustical measurements were performed.

3.9 SMU (Slovak Republic)

Sound level meter: Rion type NL18
Sound calibrator: Brüel & Kjær type 4231

3.9.1 **Initial adjustment**

The sensitivity of the sound level meter was checked with the sound calibrator supplied. The meter had already been measured at NPL, and no adjustment was required showing that the instrument had not changed in sensitivity.

3.9.2 **Equipment**

Function/ Arbitrary Waveform Generator type HP 33120A
Attenuator type RFT Xa716
RFT DC-AC-R Digital Multimeter type G12.12.010
Brüel & Kjær Microphone Preamplifier type 2619
Brüel & Kjær Frequency Analyser type 2120
Brüel & Kjær electrostatic actuator with voltage source in calibration apparatus type 4142
Oscilloscope

3.9.3 **Methods**

Steady level linearity and under-range indication: Measurements performed for time weighting F only at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges, but a reference level of 85 dB rather than the expected 94 dB was used. However it appears that the level linearity error was not quite calculated according to the definition given in 1CDV, but the reference level was adjusted at 1kHz, and this level was used as reference for all frequencies.

Toneburst response for conventional sound level meters: Additional measurements for tonebursts not included in annex B were also performed.

Toneburst response for integrating-averaging sound level meters: No measurements were made for L_{eq}. Additional measurements for tonebursts not included in annex B were also performed for SEL.

Overload indication: Measurements were performed in terms of the increase in input signal level necessary to obtain the first indication of overload.

Peak C-weighted sound pressure level: Measurement according to 1CDV showed problems due to the noise floor of the instrument at the lowest measurement point on the reference range, so a measurement was not performed at that point. No measurements were performed on the most sensitive range. Measurement levels were taken as peak values rather than the steady r.m.s level specified in annex B.

Accuracy of indication at 1 kHz and other acoustical tests: Accuracy of indication at 1 kHz was performed using the associated sound calibrator. Other acoustical tests were performed using an electrostatic actuator, over the frequency range 20 Hz to 20 kHz in one-third octaves, to determine the frequency response of the microphone only. The reference point was the output voltage level from the microphone at 250 Hz.

3.10 IA-CSIC (Spain)

Sound level meter: Cesva type SC-20c
Sound calibrator: Cesva CB-5

3.10.1 **Initial adjustment**

The sound calibrator was calibrated using a Brüel & Kjær type 4180 microphone. The values obtained were 93.6 dB for the nominal 94 dB setting, and 103.6 dB for the nominal 104 dB setting. Following the manufacturer's instructions the sound level meter was adjusted to read 93.4 dB when this sound calibrator was applied.

3.10.2 **Equipment**

HP Multifunction Synthesiser type 8904
Brüel & Kjær Signal Analyser type 2035 (Generator and Sampling Module type 3106)
HP Multimeter type 3458
DANBRIDGE Decade Attenuator type DA3HS/D
Philips Digital Oscilloscope type PM 3323
Promax DC Power Supply type FAC-664

3.10.3 **Methods**

Frequency weightings: Electrical measurements were performed over the frequency range 10 Hz to 20 kHz in one-third octave intervals - more frequencies than are required by annex B.

Steady level linearity and under-range indication: Measurements performed for both time weighting F and L_{eq} at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz, and additionally at 4 kHz. The starting points at other frequencies were calculated, and the measured electrical frequency response was used in the calculation of level linearity error, which was performed according to the definition given in 1CDV.

Toneburst response for conventional sound level meters: Measurements were performed at several levels using all the different length tonebursts specified in the standard, rather than restricting the testing to the annex B requirements. Exponential time constants were also measured.

Toneburst response for integrating-averaging sound level meters: Measurements were performed at several levels using all the different length tonebursts specified in the standard, rather than restricting the testing to the annex B requirements.

Overload indication: This was measured for continuous and toneburst signals for A and C weighting. The test required by annex B was also performed, in terms of the indication at which overload first occurred.

Peak C-weighted sound pressure level: Measurements were performed at 3 levels, and a mean response obtained.

Accuracy of indication at 1 kHz and other acoustical tests: Due to problems with the free-field facility it has not as yet been possible to report any results for this project.

3.11 SP (Sweden)

Sound level meter: Brüel & Kjær type 2230
Sound calibrator: Brüel & Kjær type 4231

3.11.1 **Initial adjustment**

The acoustical sensitivity was checked by use of the sound calibrator, using the manufacturer's instructions to adjust for free-field use.

3.11.2 **Equipment**

Generator type HP 3325
Function Generator type HP 8116
Function Generator type HP 8904
Attenuator
FFT Analyser type HP3562
Brüel & Kjær microphone type 4134
Brüel & Kjær multi-function calibrator type 4226

3.11.3 **Methods**

Frequency weightings / responses: The HP 3325 generator level was considered to be constant at all frequencies.

Steady level linearity and under-range indication: The HP 3325 generator level was considered to be constant at all frequencies. At lower levels an external attenuator was used. Measurements performed for both time weighting F and L_{eq} (measured over 30s) at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges. However it appears that the definition of level linearity error was misunderstood and results were referred to the starting point on the range rather than calculating the error according to the definition given in 1CDV.

Toneburst response for conventional sound level meters: The tonebursts were generated by the HP 8116 function generator, which was an old generator not normally in use. The generator in normal use, the HP 8904, is not capable of generating signals shorter than 1 ms. At longer bursts no difference was found between the generators.

Toneburst response for integrating-averaging sound level meters: The tonebursts were generated by the HP 8116 function generator, which was an old generator not normally in use. The generator in normal use, the HP 8904, is not capable of generating signals shorter than 1 ms. At longer bursts no difference was found between the generators.

Overload indication: Measured in terms of the generator voltage necessary to produce an indication of overload. As the generator available (HP 8116) could not generate half-cycle signals, these were obtained by connecting a diode between the generator and the dummy microphone to cut off one half of the pulse. The FFT analyser, in the time domain, was then used to monitor the applied signal.

Peak C-weighted sound pressure level: The HP 8904 was used to generate all the pulses apart from 8 kHz where the HP 8616 was used. At lower levels an external attenuator was used. Measurement according to 1CDV showed problems due to the noise floor of the instrument on the most sensitive range.

Accuracy of indication at 1 kHz and other acoustical tests: Accuracy of indication at 1 kHz was measured using a multi-function sound calibrator. Other acoustical tests were performed in a hemi-anechoic room with the sound source flush mounted in the floor. A Brüel & Kjær type 4134 was used as reference, using the manufacturer's nominal free-field corrections. Six measurements were performed at different positions at the octave frequencies between 63 Hz and 16 kHz, using 1 kHz as the reference.

3.12 OFMET (Switzerland)

Sound level meter: Rion type NL15
Sound calibrator: Brüel & Kjær type 4230

3.12.1 Initial adjustment

The sensitivity of the sound level meter was checked with the sound calibrator supplied. The meter had already been measured at NPL, but needed to be adjusted.

3.12.2 Equipment

Generator type HP 3325A
Fluke RMS Voltmeter

GDS Attenuator
Brüel & Kjær Sine/ Noise Generator type 1049
Brüel & Kjær Test Waveform Generator type 5918
Datron DMM type 1081
DVM type HP 3455
Le Croy Arbitrary Function Generator
HP FFT Analyser type 3561
Brüel & Kjær Microphone type 4180
Loudspeaker

3.12.3 **Methods**

All measurements were performed outside the given static pressure range. However no pressure coefficient data was available for either the sound level meter or sound calibrator, so no corrections were made to the sound level meter indications.

Frequency weightings / responses: Electrical measurements performed through a 11 pF capacitance, and the generator stability was monitored.

Steady level linearity and under-range indication: Measurements performed only for time weighting F at the required frequencies of 31.5 Hz, 1 kHz and 12.5 kHz on all ranges. However it appears that the definition of level linearity error was misunderstood and results were referred to the starting point on the range rather than calculating the error according to the definition given in 1CDV.

Toneburst response for conventional sound level meters: Measurements were performed for both A and C-weightings.

Toneburst response for integrating-averaging sound level meters: A repetition rate of 60/min was used for the tonebursts.

Overload indication: Method used is not very clear but seems to be in terms of a dB indication.

Peak C-weighted sound pressure level: This facility was not provided on this sound level meter.

Power supply: The instrument did not have a reset facility.

Accuracy of indication at 1 kHz and other acoustical tests: These were performed in an anechoic room using the DC output from the sound level meter and a half-inch laboratory standard microphone as reference, but some problems are known to have occurred at frequencies other than 1 kHz.

4 RESULTS AND DISCUSSION

4.1 General

At the request of some manufacturers who wished the results for their meter to be treated in confidence, each meter tested has randomly been allocated a letter. Hence from here onwards the sound level meters will be identified as meter A, meter B etc. Where one meter was tested by 2 different participants it has been allocated two letters. The participants have been informed of the identification letter for the instrument they tested. Results from participants were usually supplied in the form of internal reports, some quite detailed and some quite brief. Also some data was supplied in the form of spreadsheets. Further information was provided by fax or email.

The results are given in terms of the differences between the results measured by NPL and the participating laboratory for each meter for each test, the subclause number from IEC 61672 being given in brackets. Some difficulties arise in the comparisons because often tests were not performed at the same signal levels. Sometimes this was due to lack of technical information as required by IEC 61672, and sometimes to use of, for example, actual measured upper boundaries of a range rather than the nominal upper boundary specified. Where a nominal level is to be used this needs to be made clear in IEC 61672.

When comparing the differences in the results obtained, consideration needs to be given to the range of uncertainties of measurement reported in Section 5.2.

One of the main aims of this project was to report findings back to the relevant IEC WG - WG4. Items coming into this category are included in bold typeface in the relevant section of the results.

4.2 Preliminary inspection (B.3)

Only 8 of the 12 participants included any reference to a preliminary inspection in their reports. In one instance a fault was reported with one segment of the display.

4.3 Acoustical sensitivity (B.4.1)

This is the initial adjustment with the supplied calibrator. Where NPL measured the meter first, the indication of the sound level meter following adjustment was supplied to the participant, who was asked to note the indication and then adjust if necessary. Where NPL measured the device following another participant the calibrator was applied and the indication noted, the meter then being tested as received.

Table 3 Indication of sound level meters A - F in response to applied sound calibrator

Tester	Sound level meter indication in response to applied sound calibrator (dB)					
	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
NPL	93.9	93.9	114.0	93.2-93.4	93.8	113.8
Participant	93.9	93.9	114.0	93.9	93.9	113.8

Table 4 Indication of sound level meters G - K in response to applied sound calibrator

Tester	Sound level meter indication in response to applied sound calibrator (dB)				
	Meter G	Meter H	Meter I	Meter J	Meter K
NPL	94.0	94.2	93.7	114.0	94.0
Participant	94.0	94.2	93.9	114.0	93.4

In most cases the manufacturer's instructions were followed, but in one case the required free-field correction was not applied.

4.4 Environmental conditions (B.4.2)

NPL software did not permit measurements to be performed if the environmental conditions were outside the limits given in B.4.2, and it is assumed this was also for the case for the participants who did not report any problems meeting the conditions. Of the 6 participants who reported that some tests were performed outside the limits specified (although often only marginally) none had applied corrections to the sound level meter indications, either because the effects were described as negligible by the manufacturer or because there was no available data on corrections to apply.

4.5 Accuracy of indication at 1 kHz under reference conditions (B.5.2)

NPL measurements were all performed under free-field conditions, as was the case for some other participants (marked ff in the table below). Some however just repeated the acoustical sensitivity check from B.4 or used an equivalent method by applying a sound calibrator (marked c in the table below). According to IEC 61672 this method is only applicable where measured data are available to take account of the difference at 1 kHz between the free-field response in the reference direction and the pressure response of the sound level meter. This data should preferably be independently verified, and needs to cover the effects of reflection and diffraction around the instrument case. It is not always clear from the data supplied by some participants whether the information they used was specific to the model of sound level meter under test. All measurements were performed with A-weighting selected.

Table 5 Accuracy of indication at 1 kHz of sound level meters A - F

Tester	Accuracy of indication at 1 kHz (dB)					
	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
NPL	-0.4 ff	-0.2 ff	-0.1 ff	-0.7 ff	-0.3 ff	-0.4 ff
Participant	0 c	0 c	+0.2 ff	-0.1 ff	0 c	0 c

Table 6 Accuracy of indication at 1 kHz of sound level meters G - K

Tester	Accuracy of indication at 1 kHz (dB)				
	Meter G	Meter H	Meter I	Meter J	Meter K
NPL	-0.1 ff	-0.2 ff	-0.8 ff	-0.1 ff	+0.1 ff
Participant	0 ff	+0.2 ff	+0.1 ff	0 c	0 c

It is clear that where the participants used a sound calibrator they were using the same data as for the acoustical sensitivity adjustment under B.4. Assuming the meter shows no short-term drift it is inevitable that the accuracy of indication will be shown as 0 here. This demonstrates the need for the independent certification of the 'correction data' supplied by the manufacturer. Where both NPL and the participant made a free-field measurement, agreement is within the measurement uncertainties for all meters except meters D and I. Meter D has shown a drift in sensitivity and if the NPL results are adjusted by the known drift as demonstrated by applying the sound calibrator, a figure of -0.1 dB is obtained, again giving good agreement. The difference with Meter I is harder to explain - repeat measurement at NPL confirmed the figure, although some problem was found in aligning the meter accurately with the sound source, due to the mounting position on the meter. There was no time to have a special adapter made, but it was verified that this was not having a significant effect. Also, the method used by the participating laboratory and NPL differed, and the meter was in general found to vary in indication somewhat. Probably more important was that no sound calibrator was supplied with the instrument, so the difference could possibly be explained by the initial and any subsequent adjustment of the meter. The microphone design differs from many working standard microphones, and no data was available on the level to be expected with different models of sound calibrator. Indeed some measurements with the meter under test and another meter type placed 'face-to-face' simulating a 'pressure' situation showed inconsistencies of the order mentioned above, implying a problem with the microphone / calibrator combination.

4.6 Frequency weightings; frequency responses (B.5.3)

This test was based on B.5.3 of IEC 61672, but only the results of the electrical measurements normalised to 1 kHz were required. Very good agreement was found with all the testing laboratories. The tables below show the difference which occurred most often between NPL and the participating laboratory, and the greatest difference found for any of the frequency weighting / responses tested.

Table 7 Differences in measurement of electrical frequency-weightings/responses between the co-ordinating laboratory and the participating laboratory for sound level meters A - F

	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
Difference occurring most often (dB)	0	0.1	0.1	0.1	0	0.1
Maximum difference (dB)	0.2	0.2	0.2	0.2	0.3	0.1

Table 8 Differences in measurement of electrical frequency-weightings/responses between the co-ordinating laboratory and the participating laboratory for sound level meters G - K

	Meter G	Meter H	Meter I	Meter J	Meter K
Difference occurring most often (dB)	0	0	No comparison possible	0.1	0
Maximum difference (dB)	0.2	0.1	-	0.2	0.1

4.7 Steady level linearity and under-range indication (B.5.4)

This test was the most misunderstood of all the tests performed under annex B. Of the 12 participants only the co-ordinating laboratory and one other appeared to perform the tests exactly as intended and calculated the level linearity error according to the definition given in 1CDV. Two other laboratories went most of the way towards doing this. The confusion arises because a starting point is defined for ranges other than the reference range at 1 kHz, and for all the ranges at the other frequencies. Almost all the remaining participants used this starting point as the reference point, and checked the linearity with reference to that. **The text is ambiguous and needs to be re-written so that it can easily be understood**. Also many of the laboratories did not perform tests for both time-weighting F and L_{eq}, feeling that the test was too lengthy and detailed for annex B. **The number of test points needs to be reduced.**

Hence detailed comparisons of results are not feasible for this test, but where some comparison could be made good agreement between NPL and the participants was found, usually within 0.2 dB.

The measurement of overload points appeared to generally agree well usually within 1 - 2 dB, although there clearly was some variation on a day-to-day basis. The same was also true for the under-range point or the limit of the range where the instrument no longer met the standard, but of course this was clouded by the incorrect calculation of level linearity errors. Also, it was difficult for some manufacturers to supply the range definitions needed as these meters were not manufactured according to IEC 61672. This problem should not occur with instruments designed to the new standard as this information will be required for the different frequencies in the instruction manual.

Some problems were reported in obtaining steady indications at 31.5 Hz with time-weighting F due to the natural ripple from the detector, which caused variations of ± 0.1 dB. It was noted that S time-weighting, if available, may be used but this requires a longer 'settling time', otherwise several readings with F time-weighting may need to be recorded.

4.8 Toneburst response for conventional sound level meters (B.5.5)

There were some differences in interpretation here over the upper boundary of the range, meaning in some cases measurements were performed at slightly different levels. Nevertheless good agreement was shown in most cases. The tables below show the maximum differences in the results between the co-ordinating laboratory and the participating laboratory for A-weighting and bursts of duration 0.25 ms, 5 ms and 100 ms for time-weighting F, and for bursts of duration 2 ms, 20 ms and 500 ms for time-weighting S.

Table 9 Maximum difference in measurement of time-weighting F between the co-ordinating laboratory and the participating laboratory for sound level meters A - F

	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
Maximum difference for time-weighting F (dB)	1.3	0.1	0.1	0.2	0.2	0.1

Table 10 Maximum difference in measurement of time-weighting F between the co-ordinating laboratory and the participating laboratory for sound level meters G - K

	Meter G	Meter H	Meter I	Meter J	Meter K
Maximum difference for time-weighting F (dB)	0.3	0.3	0.9	0.1	0.2

Table 11 Maximum difference in measurement of time-weighting S between the co-ordinating laboratory and the participating laboratory for sound level meters A - F

	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
Maximum difference for time-weighting S (dB)	0.4	0.1	0.1	0.1	0.3	0.1

Table 12 Maximum difference in measurement of time-weighting S between the co-ordinating laboratory and the participating laboratory for sound level meters G - K

	Meter G	Meter H	Meter I	Meter J	Meter K
Maximum difference for time-weighting S (dB)	0.1	2.1	0.1	0.1	0.1

For meter A, NPL results were close to the design goals, but those of the participating laboratory differed for two of the tonebursts applied. However repeat measurements at the participating laboratory confirmed their results, so no explanation is available for the large difference found. Meter H showed large differences for the shortest toneburst, but it is thought that this is due to the varying performance of the meter itself, as it was not meeting the design goal within the tolerances for this toneburst. For meter I and time weighting F, a possible explanation for the large difference, which was observed with the shortest toneburst, could be the measuring time where a large dispersion of values was observed particularly for the first indication of the maximum level. The participating laboratory therefore used 4 successive bursts separated by 5 s in order to obtain a steady displayed level.

4.9 Toneburst response for integrating-averaging and integrating sound level meters (B.5.6)

Again there were some differences in interpretation over the upper boundary of the range, resulting in some measurements being performed at slightly different levels. Nevertheless good agreement was shown in most cases. The tables below show the maximum differences in the results between the co-ordinating laboratory and the participating laboratory for A-weighting for sound exposure level, for bursts of duration 0.25 ms, 5 ms and 100 ms. Results are also shown for measurement of L_{eq} for a sequence of bursts of the same duration over the period of 60 s. The number of tonebursts in the sequence had to be at least 10. Several participants omitted this test, not realising it was a separate test to sound exposure level. **The two tests should be separated into different subclauses in the next draft of the standard to avoid confusion.**

Table 13 Maximum difference in measurement of sound exposure level between the co-ordinating laboratory and the participating laboratory for sound level meters A - F

	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
Maximum difference for SEL (dB)	0.3	0.1	0.1	0.1	0.4	0.1

Table 14 Maximum difference in measurement of sound exposure level between the co-ordinating laboratory and the participating laboratory for sound level meters G - K

	Meter G	Meter H	Meter I	Meter J	Meter K
Maximum difference for SEL (dB)	0.1	0.6	0.4	0.2	0.2

Table 15 Maximum difference in measurement of L_{eq} between the co-ordinating laboratory and the participating laboratory for sound level meters A - F

	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
Maximum difference for L_{eq} (dB)	-	0.4	0.1	0.1	0.5	-

Table 16 Maximum difference in measurement of L_{eq} between the co-ordinating laboratory and the participating laboratory for sound level meters G - K

	Meter G	Meter H	Meter I	Meter J	Meter K
Maximum difference for L_{eq} (dB)	0.9	0.6	0.4	0	0.3

The largest differences occurred for the shortest burst durations, so may be a function of the instrument. These differences seem to occur when the meter response is not very close to the design goal, but nevertheless all the meters would still conform to the standard.

4.10 Overload indication (B.5.7)

There was confusion over the methods to be used for this test. Some participants recorded the meter indication the first time an overload occurred, some recorded the indication just prior to overload, some measured the level of the continuous signal from which the half-cycle signal was extracted and some measured the level of the input signal necessary to cause the first indication of overload. **The method needs to be expanded and clarified in the next draft version of the standard.**

As the methods used varied it is not feasible to produce a meter-by-meter comparison. However good agreement was shown between the responses to the positive and negative half-cycles, and where comparison was possible the response between the two polarities agreed well. The actual point of overload appears to vary on most meters by a small amount on different occasions.

4.11 Peak C-weighted sound pressure level (B.5.8)

As was expected participants found these measurements quite difficult to perform, and the results showed a reasonably large spread. However in most cases this did not affect whether or not the meter would conform to the standard. The main difficulty in comparing these results is that often measurements were performed at different levels. In some cases this was due to lack of technical information appropriate to IEC 61672, but in some cases annex B appeared not to have been followed in respect of the level of the steady sinusoidal signal. Also, as stated earlier, it is not possible to obtain sensible results at the lowest points on the most sensitive ranges, due to the noise floor, and indeed similar problems were encountered in some cases on the reference range. **The text of annex B needs to be modified to omit tests where the noise floor is affecting the result, and it needs to be considered whether it is sensible to prescribe tests of C-weighted peak on the most sensitive range. In practice users would generally use higher ranges to measure peak C-weighted SPL.** Hence participants had measured at different levels and at a different number of levels, so comparison is difficult. The following tables show the maximum differences between the participating laboratory and the co-ordinator, but it should be remembered that these cover all the test points which could be compared on the two different ranges, with the exception of the lowest point on the most sensitive range which has been excluded. However, it is not the intention that this table should be taken as showing any information of particular significance in comparing peak measurements from different laboratories.

Table 17 Maximum differences in measurement of peak C-weighted sound pressure level between the co-ordinating laboratory and the participating laboratory for sound level meters A - F

Maximum difference with applied signal (dB)	Meter A	Meter B	Meter C	Meter D	Meter E	Meter F
31.5 Hz one cycle	0.2	0.3	1.0	0	0.1	-
500 Hz one cycle	0.1	0	0.1	0.1	0.3	-
8 kHz one cycle	0.1	0	0.5	0.2	0.6	-
500 Hz + half cycle	0	0.2	0.5	0.1	0.4	0.5
500 Hz - half cycle	0.3	0	0.4	0.1	0.4	1.0

Table 18 Maximum differences in measurement of peak C-weighted sound pressure level between the co-ordinating laboratory and the participating laboratory for sound level meters G - K

Maximum difference with applied signal (dB)	Meter G	Meter H	Meter I	Meter J	Meter K
31.5 Hz one cycle	0.6	-	0.6	-	0.1
500 Hz one cycle	0.6	-	0.8	-	0.2
8 kHz one cycle	0.5	-	0.8	-	0
500 Hz + half cycle	0.7	-	0.6	-	0.1
500 Hz - half cycle	0.5	-	0.8	-	0.2

4.12 Reset (B.5.9)

This test was successfully performed by all participants, where the facility was available.

4.13 Power supply (B.5.10)

It is assumed that most participants performed this test using a separate power supply, rather than waiting for the batteries to discharge, but the actual method was not specified by all participants. The largest difference in indication on application of the calibrator driven by the different voltages prescribed was 0.1 dB. In some cases the lowest voltage level for correct operation of the instrument was not always evident from the accompanying literature.

4.14 Additional acoustical tests (B.5.11)

Some participants performed additional acoustical measurements in a free-field, some by using a sound calibrator or electrostatic actuator and in some cases no other acoustical measurement were performed, so a direct comparison of results is not always possible. Only a limited number of frequencies was required by the test protocol, so a considerable amount of data here is additional. However this means the tests were not as well defined as the others in this project and there has been no opportunity to look for detailed reasons for any differences in the responses measured by the different laboratories. Also on some occasions the same weighting or response was not measured by NPL and the participating laboratory, and in some cases results have been normalised to 1 kHz. Nevertheless reasonable agreement is generally demonstrated as shown in the following Figures, particularly when uncertainties of measurement are taken into consideration. However it is recommended that a separate Euromet project be considered at some future date to look more closely at free-field testing of sound level meters. Some more detailed analysis at 1 kHz has already been given in 4.5, but the confidentiality requirements mean it is difficult to discuss these results more thoroughly. For meter C there is some evidence to show that the meter sensitivity was adjusted by about 0.4 dB between the acoustical measurements at NPL and at the participating laboratory.

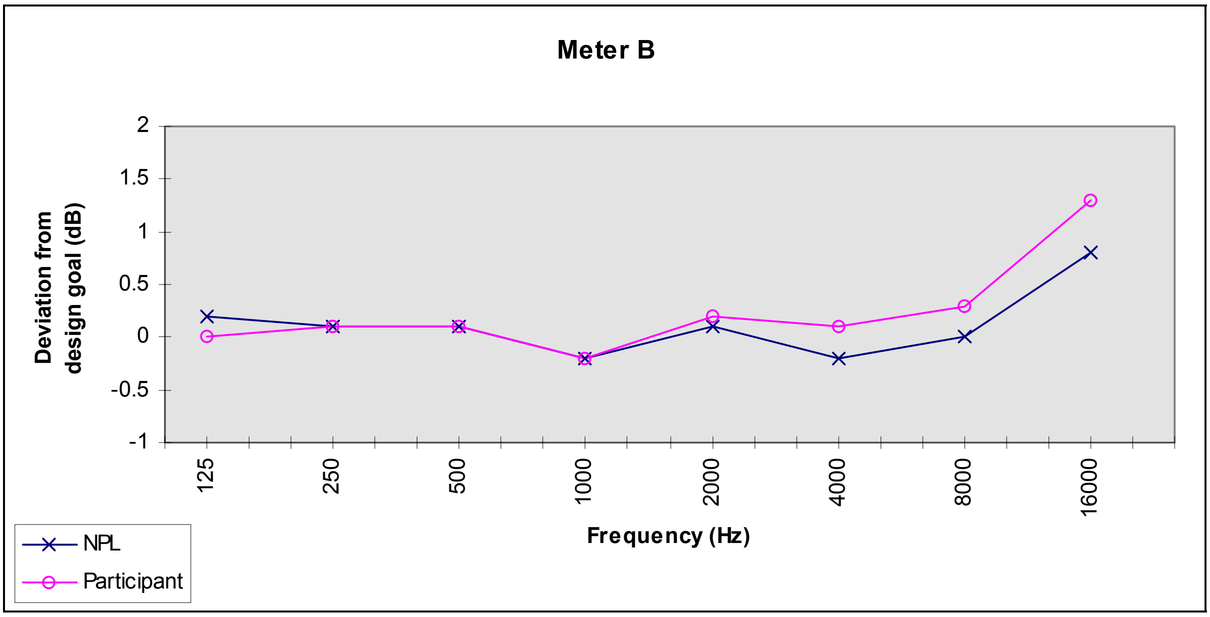

Figure 1 Deviations from design goal for sound level meter B for frequency response 'LIN'

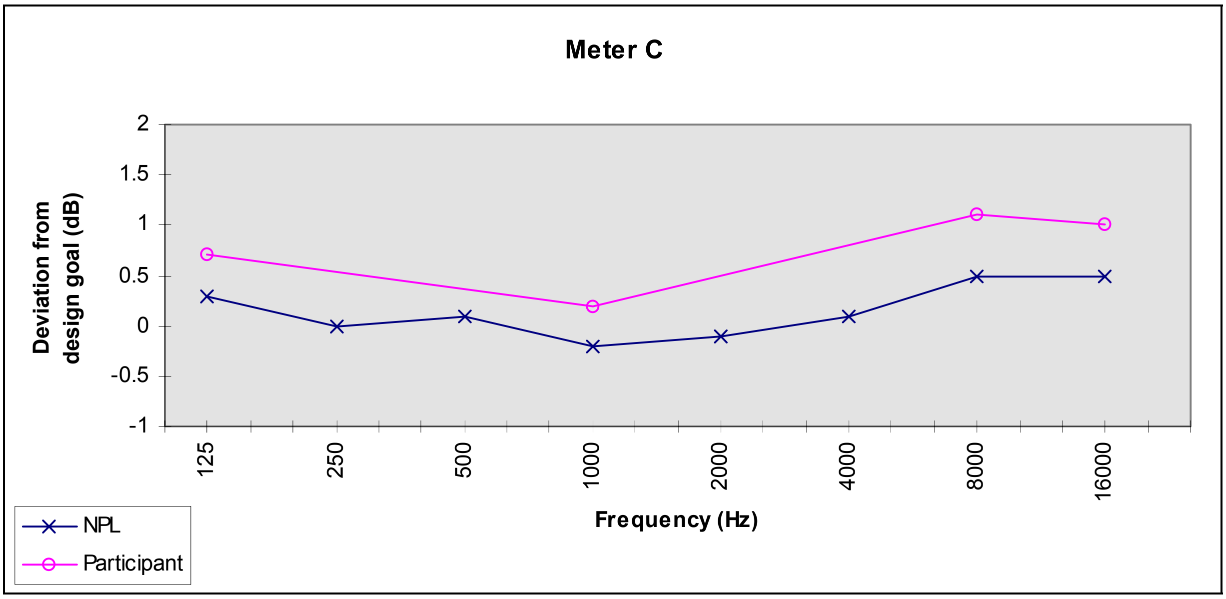

Figure 2 Deviations from design goal for sound level meter C for frequency weighting C (NPL) and for frequency weighting A (participant)

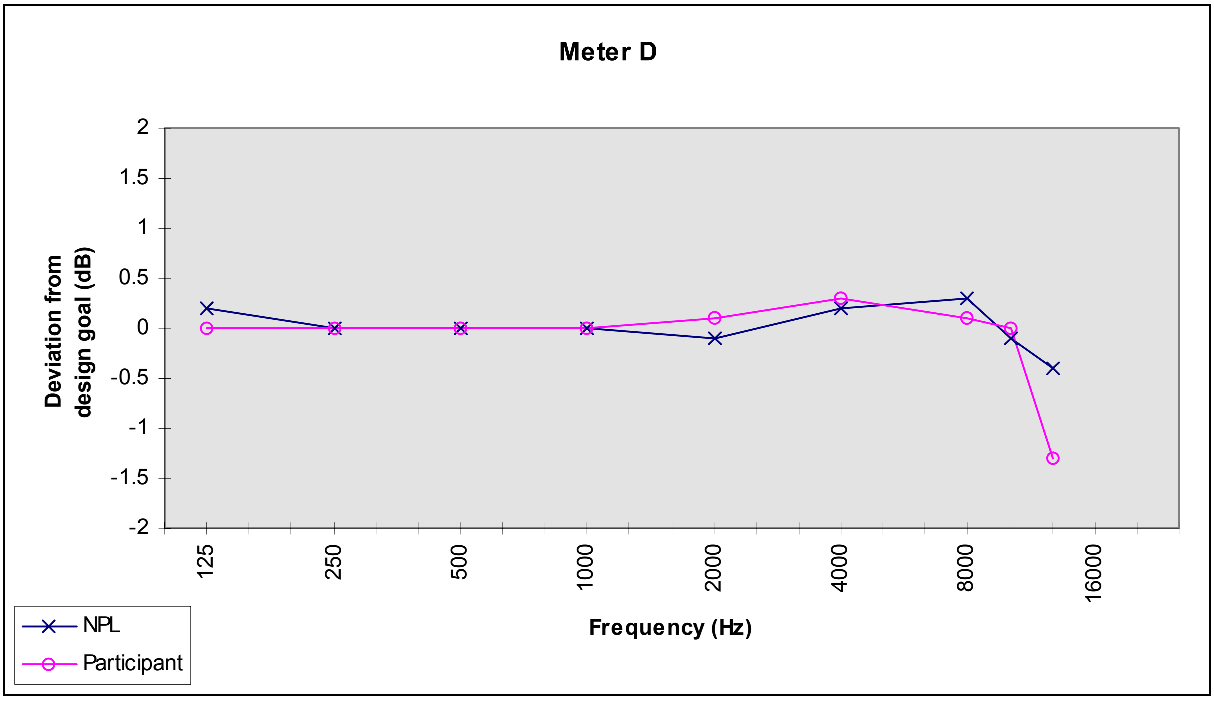

Figure 3 Deviations from design goal for sound level meter D for frequency weighting C (NPL) and for frequency response Lin. (participant) normalised to 1 kHz

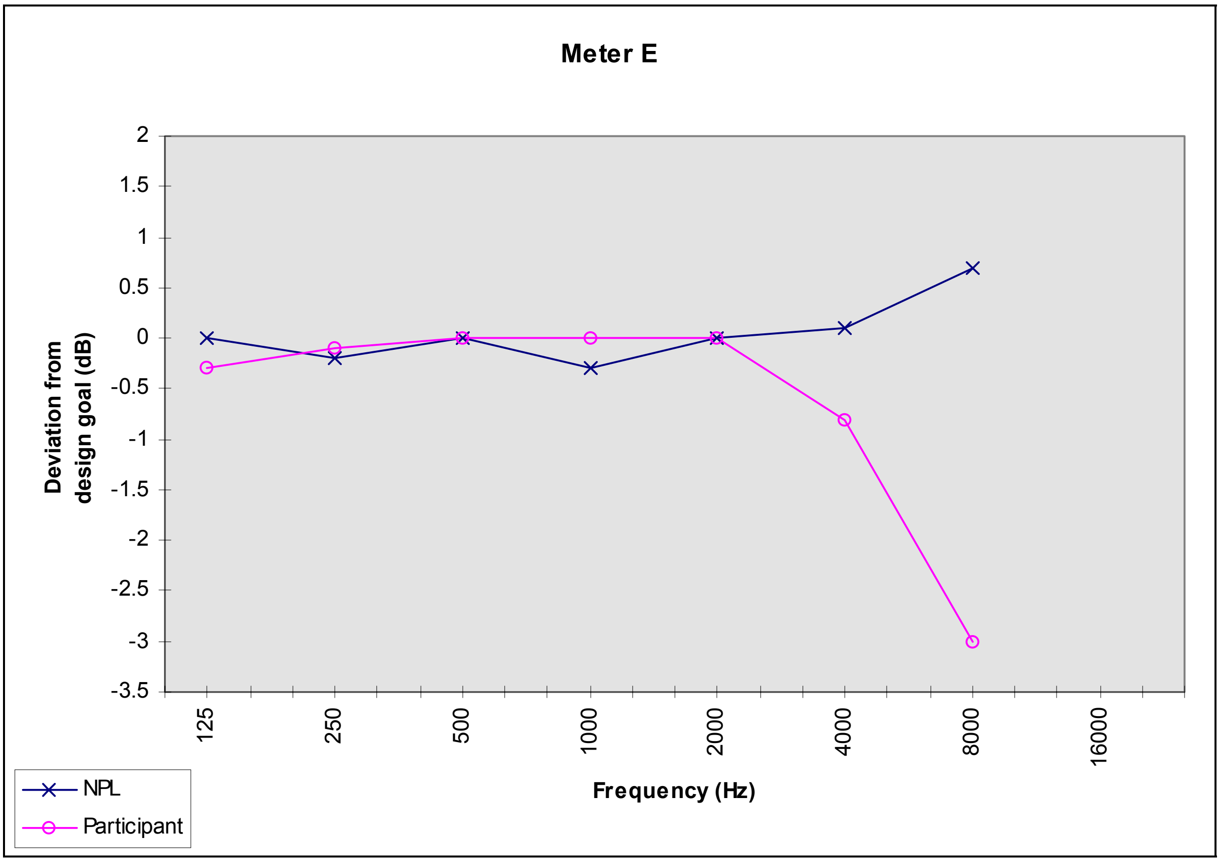

Figure 4 Deviations from design goal for sound level meter E for frequency weighting C

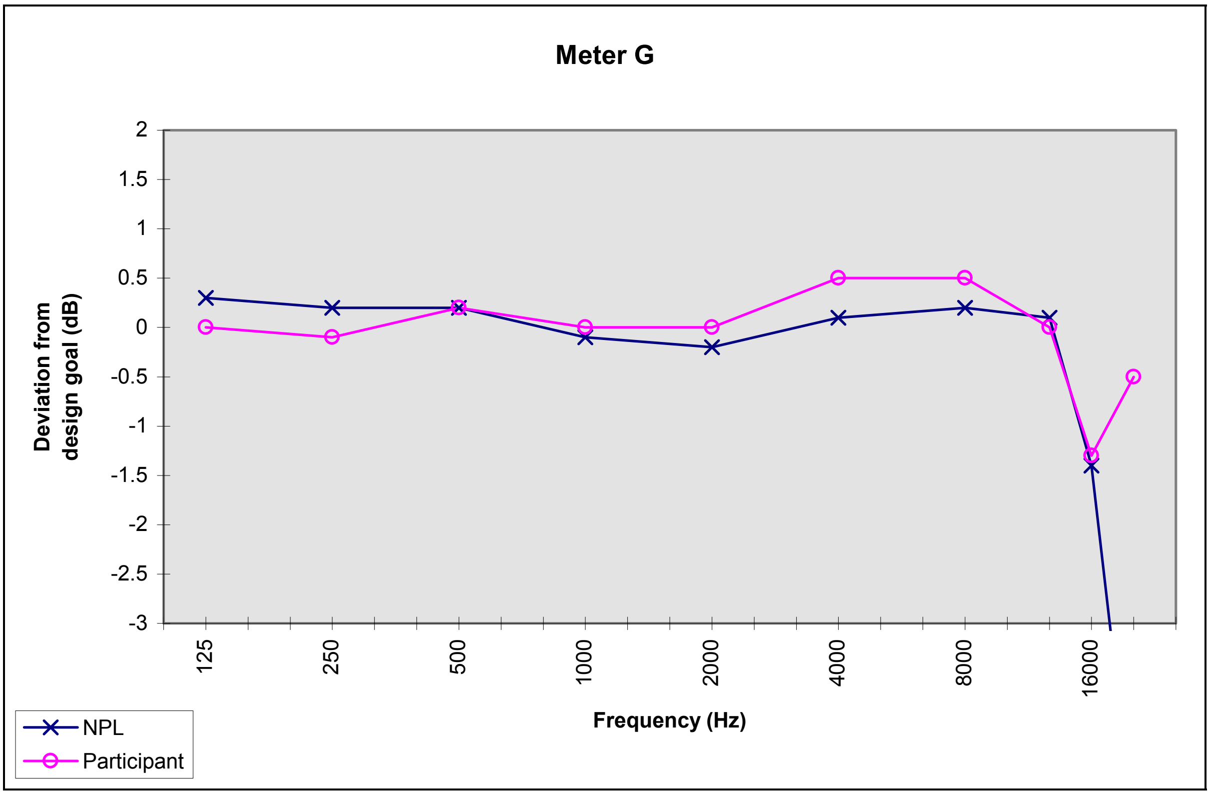

Figure 5 Deviations from design goal for sound level meter G for frequency weighting A

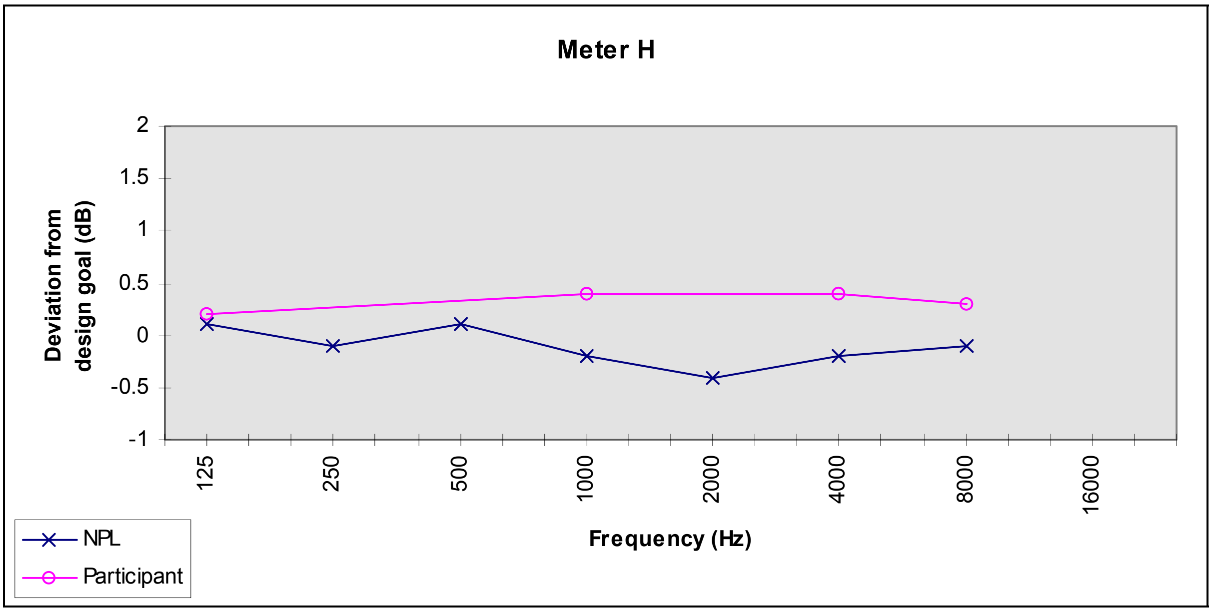

Figure 6 Deviations from design goal for sound level meter H for frequency weighting C (NPL) and for frequency weighting A (participant)

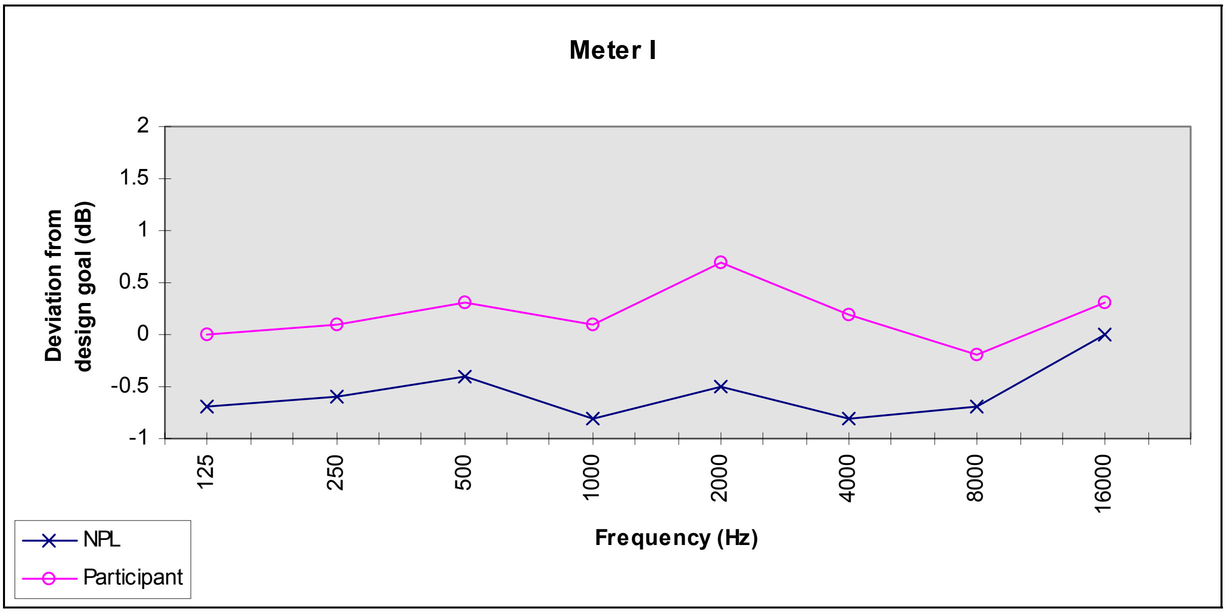

Figure 7 Deviations from design goal for sound level meter I for frequency weighting C

5 CONCLUSIONS

5.1 Conformance with IEC 61672

Although demonstrating whether or not the instruments tested conformed with IEC 61672 was not one of the main aims of the project, it is nevertheless interesting to consider how the meters performed. In should be borne in mind that all the meters tested were Type 1 under the existing IEC 60651 and IEC 60804 and had not been designed specifically to meet IEC 61672. The problem areas already identified for the peak C-weighting measurements apart, the only other area which showed several failures was at the bottom and, in some cases, at the top of ranges. This seemed to largely be due to lack of exact technical specification, which should not occur when the meter is identified as being manufactured to IEC 61672. In most cases the range specified was 1 or 2 dB more than was found in practice before the meter failed the standard on level linearity errors. One meter failed all the half-cycle tests for the peak C-weighting measurement, and would not respond correctly to the half-cycle overload test when measured by the participant, but passed most of the peak tests at NPL. For another meter NPL found a failure for some of the half-cycle tests, but this was not found by the participating laboratory. One meter was found to fail time-weighting F for two toneburst durations by the participant although it passed at NPL, and another meter was found to fail time-weighting S by both the participant and NPL for the shortest duration burst, as well as an additional failure for the longest duration burst at NPL. The participant also reported failure for sound exposure level again for the shortest burst duration.

It is reassuring to learn that there are only two or three instances from all the results collected where one laboratory would state that the meter conformed to the standard and the other laboratory would state that it failed to conform. These instances could of course be due to the meter itself, but under this project there was no time for a re-test.

5.2 Uncertainties of measurement

As agreed at the start of the project each participant was expected to provide an analysis of uncertainties of measurement for each test performed. The method of calculation was to the ISO Guide for a coverage factor of k = 2. All participants were able to supply some data, and this is listed in the tables below. Various amounts of detail were provided, and from this it is clear that laboratories sometimes estimated the contribution from a similar component differently. Obviously the components to be included do depend on the equipment actually used, but it appears in some cases the components may have been slightly underestimated. This is particularly the case for steady level linearity as, with the exception of NPL, only one participant included the uncertainty in the measured frequency weighting, as the frequency weighting itself was not generally applied. Most uncertainty data supplied was quoted to the nearest 0.05 dB, so this practice has also been adopted for all the information supplied. The data collected has already been passed on to WG4 and has proved invaluable in deciding on the uncertainties to be included in the tolerance limits in the latest draft of IEC 61672. One of the main points of discussion was whether a semi-range error of 0.05 dB or 0.1 dB should used for the reading a digital display, which indicates to 0.1 dB. **It is suggested that a note be included in the standard giving a recommendation, as well as describing briefly the likely contributions to the uncertainty budgets.**

Table 19 Uncertainties of measurement of participating laboratories

Test	BEV	DPLA	LNE	PTB	OMH	IEN
Frequency weighting/ response	0.1	-	-	0.2	0.2	0.1
Linearity	0.1	0.2	0.1/ 0.2	0.3	0.1	0.1
Toneburst conventional	0.2	0.2	0.2	0.2	0.3	0.15
Sound exposure level and L_{eq}	0.2	0.2	0.2	0.2	0.3	0.15
Overload	0.2	-	0.1	0.2	0.3	-
Peak C-weighted SPL	0.2	-	0.2	-	0.3	0.2 - 0.3
Power supply	0.1	-	0.1	-	0.1	-
Acoustical tests: 1 kHz Other frequencies	 0.3 0.3 - 0.5	 0.2 (0.3)* 0.2 (0.2 - 1.7)*	 0.2 0.2 - 0.5	 0.3 0.3	 - -	 0.15 0.2 - 0.35

* Values in ( )s refer to method b.

Table 20 Uncertainties of measurement of participating laboratories (continued)

Test	LNEC	SMU	IA - CSIC	SP	OFMET	NPL
Frequency weighting/ response	0.1	0.2	0.2	0.1	0.2	0.2
Linearity	0.15/0.6	0.2	0.2	0.1/0.45	0.25	0.2/0.3
Toneburst conventional	0.15	0.1	0.2	0.25	0.15	0.2
Sound exposure level and L_{eq}	0.35	0.1	0.2	0.25	0.15	0.2
Overload	-	0.3	0.2	0.25	0.2	0.2
Peak C-weighted SPL	-	0.25	0.2	0.25	-	0.2
Power supply	0.1	-	0.1	-	-	0.2
Acoustical tests: 1 kHz Other frequencies	 - -	 - -	 - -	 0.25 0.25 - 0.6	 0.25 	 0.25 0.2 - 0.4

5.3 Time taken for the tests

Data was provided by only a few laboratories, as most felt it was not possible to give accurate timings as this was the first time the tests had been performed, and so were part of a learning process. Overall it was generally agreed that to perform an annex B test and to issue a Certificate, including the associated paperwork would take 1 to 2 days. One laboratory felt it would take closer to 3 days, and one who did not complete quite all the tests recorded a testing time of less than 1 day. One participant reported 3 days for completing the electrical tests but based on annex A, although the meter used had only one range. Generally, it is considered that the amount of work for annex B is likely to make the test too expensive, particularly for Class 2 meters and **WG4 should be urged to reduce the number of tests in annex B wherever possible.**

5.4 Items reported to IEC/TC29 WG4

As stated earlier, items for reporting to WG4 have been identified in the text by the use of **bold** typeface. Most of these items have already been presented to a meeting of WG4 in May 1998, and they have all been accepted. The text will be modified accordingly before the next draft of IEC 61672 is issued. A list of the points is given below:

1. Steady level linearity. The text is ambiguous and needs to be re-written so that it can easily be understood. The number of test points needs to be reduced.

2. The tests of sound exposure level and L_{eq} should be separated into different subclauses to avoid confusion and omission of one of the tests.

3. Overload indication. The method needs to be expanded and clarified.

4. Peak C-weighted sound pressure level. The text needs to be modified to omit tests where the noise floor is affecting the result. Consideration needs to be given to the wisdom of testing on the most sensitive range, when in practice this is most unlikely to be used for peak measurements.

5. It is suggested that a note be included giving a recommendation on the uncertainty contribution to be included for reading a digital display, as well as describing briefly the likely contributions to the uncertainty budgets.

6. Concern over the time taken to perform the tests - WG4 to be urged to reduce the number of tests wherever possible.

7. A statement be included stressing the need to follow the text and methods of annex B closely, in particular the signal levels to be used for each test.

5.5 Summary

This Euromet project involved national metrology institutes in the evaluation of a draft standard for the first time. It has proved extremely valuable in producing information on the difficulties encountered with the measurements, in identifying areas where the text needed modifying or clarifying, and in gathering very important data on uncertainties of measurement. Most of this information has already been passed on to the relevant international committee IEC/TC29 WG4, where it was very well received. In fact it was suggested that, if such an opportunity arises in the future to perform similar tests on other instruments, it would be very valuable if Euromet could consider undertaking a similar project. Comparison of results generally shows very good agreement with most differences well within the measurement uncertainties - a comforting thought in the search for consistency of testing in different countries. A further suggestion from the project was for a future Euromet intercomparison specifically for measurements of the free-field acoustical response of sound level meters.

Results from this project will undoubtedly ensure that, when it is published, the tests and test methods for sound level meters included in IEC 61672 will be much better defined and considered than would have been the case without this Euromet involvement.

6 ACKNOWLEDGEMENTS

The author acknowledges the financial support of the National Measurement System Policy Unit of the UK Department of Trade and Industry for the work carried out in this project by NPL. The author would also like to thank all the participants for their co-operation in this project and the manufacturers and suppliers for the loan of the instruments. At NPL thanks are due to Nigel Milton for performing the electrical tests and for various discussions on the project, to Stephen Watkins for performing the free-field tests and to Steven Wren for the sound calibrator calibrations.

7 REFERENCES

[1] International Standard IEC 60651:1979. *Sound level meters*.
[2] International Standard IEC 60804:1985. *Integrating-averaging sound level meters*.
[3] Draft International Standard, IEC 61672 - 1CDV. *Electroacoustics - Sound level meters*. IEC Document no. 29 / 362 / CDV.
[4] ISO Publication ISBN 92-67-10188-9:1995. *Guide to the expression of uncertainty in measurement.*

APPENDIX 1

LIST OF PARTICIPANTS

Mr W Vanek
Bundesamt für Eich-und Vermessungswesen
Acoustics Laboratory
Arltgasse 35
P O Box 20
A-1163 Vienna
Austria

Mr P Hedegaard
Danish Primary Laboratory for Acoustics
c/o Brüel & Kjær
Sound & Vibration A/S
Skodsborgvej 307
DK-2850 Nærum
Denmark

Mr G Banget-Mossaz
Laboratorie National d'Essais
1 rue Gaston Boissier
F-75015 Paris
France

Mr K Obermayr
Physikalisch Technische Bundesanstalt
Postfach 33 45
38023 Braunschweig
Germany

Mrs T Zsusza Farkas
National Office of Measures
H-1535 Budapest Pf. 919
Hungary

Mr C Guglielmone
Istituto Elettrotecnico Nazionale "Galileo Ferraris"
Strada delle Cacce 91
I - 0135 Torino
Italy

Ms S Antunes
Laboratório Nacional de Engenharia Civil
Av. do Brasil
1799 Lisboa
Codex
Portugal

Dr K Richter
Slovak Institute of Metrology
Karloveská Ul. 63
84255 Bratislava
Slovak Republic

Dr F Chinchurreta
Instituto de Acustica
Calle Serrano 144
28006 Madrid
Spain

Mr H Andersson
Swedish National Testing and Research Institute
Acoustics
Box 857
S -501 15
Borås
Sweden

Mr E Siegfried
Swiss Federal Office of Metrology
Lindenweg 50
CH-3084 Wabern-Bern
Switzerland

Mrs S Dowson
Centre for Mechanical and Acoustical Metrology
National Physical Laboratory
Teddington
Middlesex TW11 0LW
United Kingdom

APPENDIX 2

LIST OF SUPPLIERS OF SOUND LEVEL METERS FOR THE PROJECT

(other than those supplied by participants)

Mr E Frederiksen
Brüel & Kjær
Sound & Vibration A/S
Skodsborgvej 307
DK-2850 Nærum
Denmark

Mr J Casamajó
Dicesva S. L. (Audio & Instruments)
Villar 20
08041 Barcelona
Spain

Mr L Verberkmoes / Mr B Stuart
Meyvis en Co. B. V.
P O Box 265
4600 AG Bergen op Zoom
The Netherlands

Mr P Luquet
01 dB
111 rue de 1er Mars
69100 Villeurbanne (F)
France

Mr R Tyler / Mr G Parry
CEL Instruments Ltd
35 - 37 Bury Mead Road
Hitchin
Herts SG5 1RT
United Kingdom

Mr W Gracey / Mr I Campbell
Gracey & Associates
High Street
Chelveston
Northants
United Kingdom

Mr O-H Bjor
Norsonic AS
Postbox 24
N-3420 Lierskogen
Norway